

Time Series Combination of Station Positions and Earth Orientation Parameters

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Abstract

CATREF software developed to generate ITRF solutions was enhanced in order to rigorously combine station positions (and velocities) together with Earth Orientation Parameters (EOP). It is also well adapted for time series combination of station positions and EOP's. We present in this paper some comparative analysis of available time series solutions provided in SINEX format from 4 techniques: VLBI, SLR, GPS and DORIS.

Introduction

Up to now, the ITRF, ICRF and EOP are determined separately and consequently their consistency is difficult to assess. Since some 5 years ago, several analysis/technique centers started to make available time series of daily/weekly/monthly solutions of station positions and daily EOP provided in SINEX files. Time series combination becomes interesting since it allows, in particular, detecting and monitoring all kind of variations and discontinuities in station positions. Moreover, the inclusion of EOPs in the ITRF combination allows to improve consistency between IERS products.

Combination model

The initial model implemented in CATREF software allows simultaneous combination of station positions and velocities. A large description could be found in (Altamimi et al. 2002). Assuming that for each individual solution s , and each point i , we have position X_s^i at epoch t_s^i and velocity \dot{X}_c^i , expressed in a given TRF k .

The combination consists in estimating:

- Positions X_c^i at a given epoch t_0 and velocities \dot{X}_c^i , expressed in the combined TRF c ,
- Transformation parameters T_k at an epoch t_k and their rates \dot{T}_k , from the combined TRF c to each individual frame k .

The general combination model is given by the following equation:

$$\begin{aligned} X_s^i &= X_c^i + (t_s^i - t_0) + T_k + D_k X_c^i + R_k X_c^i \\ &\quad + (t_s^i - t_k)[\dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i] \\ \dot{X}_s^i &= \dot{X}_c^i + \dot{T}_k + \dot{D}_k X_c^i + \dot{R}_k X_c^i \end{aligned} \quad (1)$$

Using pole coordinates x_s^p, y_s^p and universal time UT_s as well as their daily time derivatives \dot{x}_s^p, \dot{y}_s^p and LOD_s , the corresponding equations are:

$$\begin{aligned}
 x_s^p &= x^p + R2_k \\
 y_s^p &= y^p + R1_k \\
 UT_s &= UT - \frac{1}{f} R3_k \\
 \dot{x}_s^p &= \dot{x}^p + \dot{R}2_k \\
 \dot{y}_s^p &= \dot{y}^p + \dot{R}1_k \\
 LOD_s &= LOD + \frac{1}{f} \dot{R}3_k
 \end{aligned} \tag{2}$$

where $f = 1.002737909350795$ is the conversion factor of UT into sidereal time. Considering $LOD = \frac{dUT}{dt}$ is homogenous to time difference, so that $\frac{1}{f} = 1$ day in time unit.

Note that the link between EOP and TRF is ensured upon the 3 rotation angles $\dot{R}1, \dot{R}2, \dot{R}3$, and their time derivatives.

In order to precisely define the datum of the combined frame minimum constraints equations were implemented in CATREF software, allowing to express the combined solution in any external frame. For more details concerning equations of minimum constraints and their practical use, see for instance Altamimi et al., (2003).

Data Analysis

Input Data

- VLBI: 24h-session sinex files over 1990-2003, provided by Goddard Space Flight Center (GSFC) VLBI Group, using the terrestrial reference frame of gsfd001 (IVS, 2003),
- SLR: weekly solutions over 1999-2002, provide by Italian Space Agency (ASI) , (Luceri, 2003),
- GPS: Official IGS weekly combined solutions over 1999-2003 (Ferland, 2003), and JPL weekly solutions over 1996-2002 available at IGS, (Heflin et al., 2003),
- DORIS: IGN-JPL weekly solutions over 1993-2003, by IGN-JPL, (Willis, 2003).

Analysis Strategy

The analysis strategy applied currently to times series combination is as follows:

- Remove original constraints and apply minimum constraints equally to all constrained solutions
- Use as they are the minimally constrained solutions

- Perform per-technique combinations (TRF + EOP), all expressed in ITRF2000 using equations of minimum constraints. At this step the per-technique combinations are obviously free from any local ties.
- Identify and reject outliers and properly handle discontinuities, using break-wise approach
- Combine the per-technique combinations adding local ties in collocation sites
- Estimate variance components and iterate as necessary.

Analysis Results

From the per technique combinations we extracted the geocenter estimates for SLR/ASI, GPS/JPL and DORIS/IGN-JPL time series as illustrated in Figure 1. These geocenter estimates are in fact weekly translation components (over the period of the available data) with respect to ITRF2000 origin, being aligned to the center of mass. While geocenter motion assessment is still a research area, we could mention that, according to Figure 1, SLR results seem to be less scattered than GPS and DORIS. Figure 1 shows also that unlike T_z component, T_x and T_y components are stable in time, with some seasonal variations. To have an idea about the magnitude of these seasonal variations, Table 1 lists the values of the annual amplitude of the geocenter components computed by:

$$dx(t) = A.\cos(2\pi f(t-t_0) + \phi) \quad (3)$$

where dx designates one of the three geocenter components: T_x , T_y , T_z . A and ϕ are annual amplitude and phase, respectively, and ($f = 1$) is the frequency in cycles per year. The SLR seasonal variations of the geocenter components seem to be more reliable than GPS and DORIS. Figure 1 depicts also the scale time variation for the above 3 solutions, converted in mm over the equator, showing no significant drift in time, while DORIS solution exhibit a shift of about 2 cm compared to ITRF2000. Figure 2 illustrates the daily scale variation of GSFC VLBI results, over approximately 10 years, showing less scatter from 1997 on, no significant drift and roughly zero mean with respect to ITRF2000. However we may distinguish some annual variations of about 3 mm amplitude.

Table1. Annual amplitude of geocenter components (mm)

Solution	T_x	T_y	T_z
SLR/ASI	2.2	3.6	3.2
GPS/JPL	4.1	7.2	15.8
DORIS/IGN-JPL	6.9	4.4	16.0

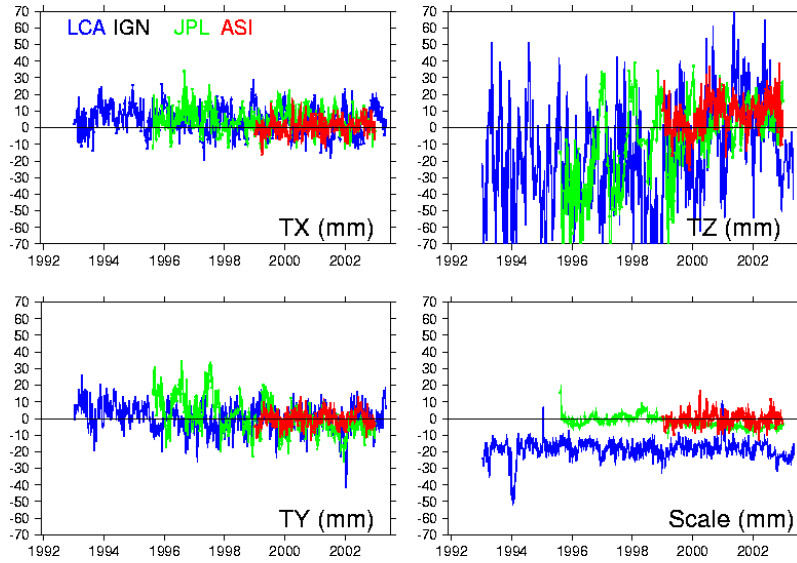


Figure 1. Origin and scale variations with respect to ITRF2000 for DORIS/IGN-JPL, GPS/JPL and SLR/ASI

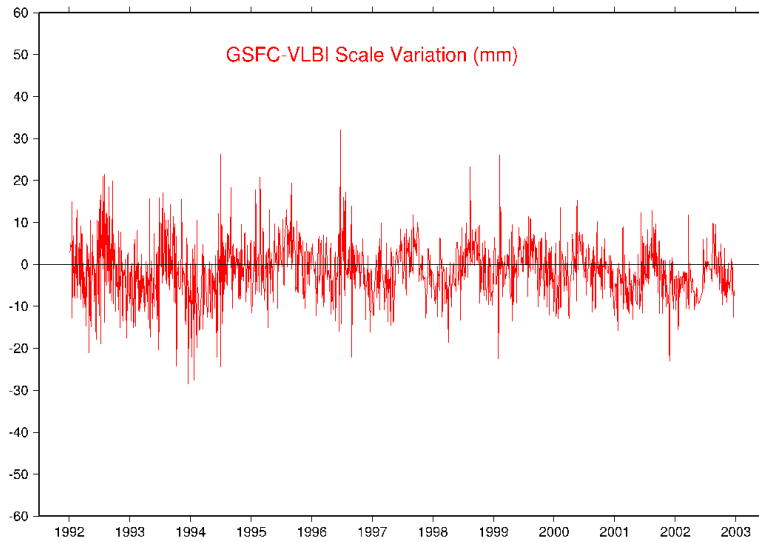


Figure 2. Daily GSFC VLBI scale variation w.r.t. ITRF2000

As results from the per technique combination, Figure 3 shows the polar motion post fit residuals (in *mas*) and Figure 4 shows the post fit residual of polar motion rates (in *mas/yr.*) and LOD (in *ms/yr.*) per technique. Moreover, Figure 5 (courtesy from D. Gambis) illustrates differences between EOP values resulted from the combination test and the IERS series C04.

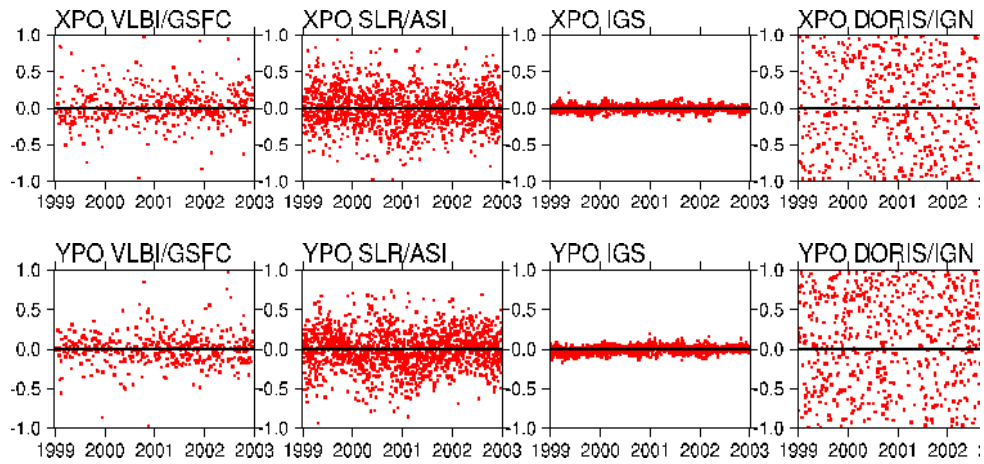


Figure 3. Post fit residual of Polar motion per technique (*mas*)

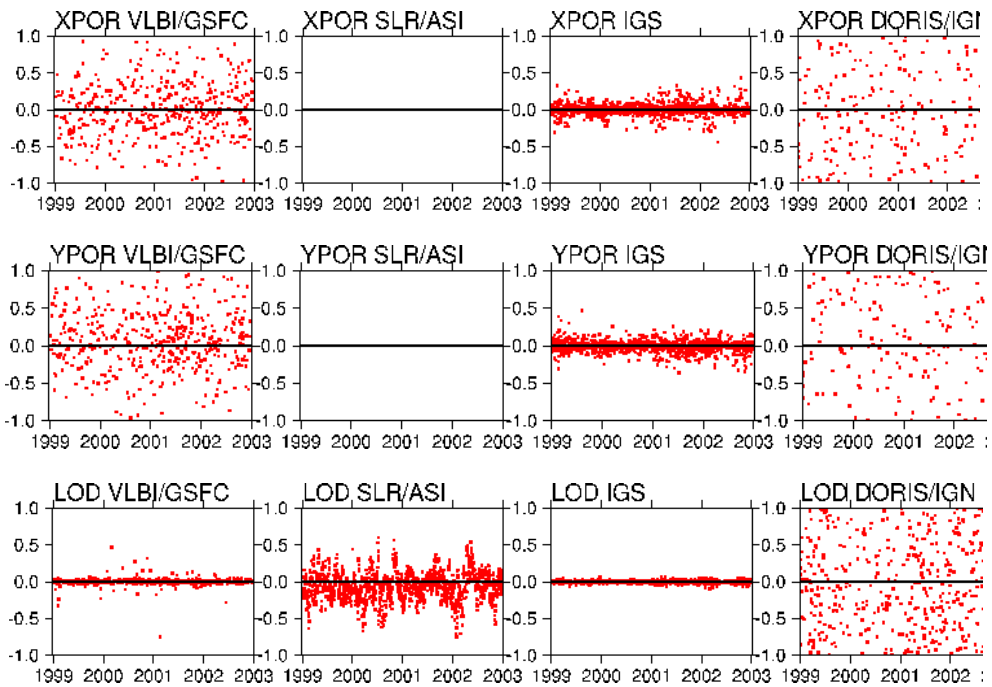


Figure 4. Post fit residual of Polar motion rates (*mas/yr.*) and LOD (*ms/yr.*) per technique

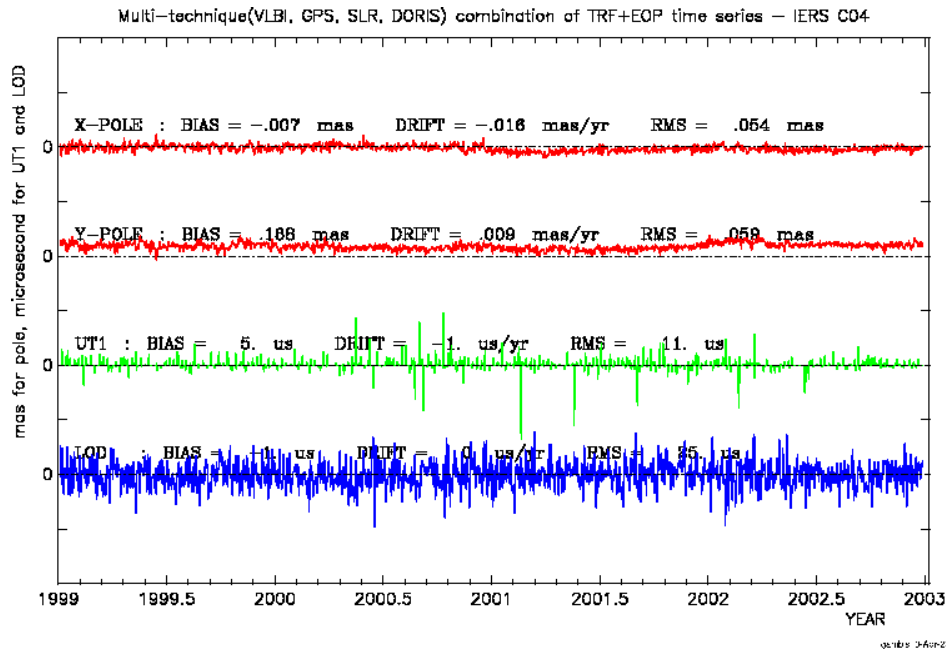


Figure 5. EOP differences with IERS C04 (*mas*) (plot courtesy from D. Gambis)

Conclusion

The EOP IGS results appear to dominate the other technique results. This is mainly due to the fact that the IGS solution is already a combination of 7 analysis centers, whereas the others are provided from one analysis center per technique. In addition, the IGS EOP estimates are based on continuous observations from more than 200 sites homogeneously distributed. From Figure 5, it clearly appears that there is a bias in the y-pole component of about 170 micro-arc-second between IERS EOP series C04 and ITRF2000.

References

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